Army Tests Remote Structural Health Monitoring for Steel Bridges

By Brett Ingold

On August 1, 2007, commuters drove across the Minneapolis I-35W Bridge to cross the Mississippi River as they would on any other day. The 1,907-foot-long bridge suddenly collapsed, killing 13 people and injuring 145. Improperly sized gusset plates, which had never been included in the bridge’s routine inspections, caused the failure.

Over the past 11 years, more than 500 bridges in the U.S. have either been taken out of service or had their load ratings reduced, and corrosion has been blamed in 100 of these cases. In addition to the potential for tragic loss of life, closing a bridge to repair or replace it can add miles to people’s daily commutes. Such closures also may affect response time for emergency vehicles.

For DoD, a bridge failure can have another serious consequence—it can impact the mission of the U.S. military. For example, at Holston Army Ammunition Plant in Tennessee, an ancient railroad bridge moves materiel between Plants A and B and is critical to the production process. The Army has more than 200 steel bridges in its inventory. Several of these bridges are considered “Fracture Critical,” which means the failure of a single component, from corrosion for example, could cause the bridge to collapse with little or no warning.

Remote Monitoring for Structural Health

The Army’s Engineer Research and Development Center (ERDC) Construction Engineering Research Laboratory (CERL), has been working to demonstrate and validate emerging, innovative technologies to remotely monitor the condition of bridges. After the Minneapolis bridge collapsed, the Office of the Secretary of Defense (OSD) directed the engineers at CERL who were analyzing the structural integrity of thermoplastic and wood bridges to expand their project’s scope to include steel bridges. The goal of their current effort is to integrate durable, low-cost sensor systems with software that will automate structural health monitoring. The system will provide advance warning of growing structural problems caused by corrosion, materials degradation, or events such as earthquakes.

“The intent is to have the system call for help,” said Christian Hawkinson, civil engineer in the Directorate of Public Works at Rock Island Arsenal, Illinois. Rock Island will serve as one of two demonstration sites for CERL’s structural health-monitoring prototype.
Existing Bridge Assessment Methods

A common practice to reduce the risk of failure on fracture-critical bridges involves labor-intensive, regular physical inspections, usually every two years. Steel bridge structures are analyzed using visual, dye penetrant, ultrasonic, and/or radiographic non-destructive inspection methods.

“These methods can detect many defects of concern, but they may not detect cracks in hidden places,” said Steven Sweeney, CERL Project Manager. “In addition, none of these methods can be used in real-time to determine if a defect is actively growing. The inspection results can lead to focusing on unimportant flaws while being unaware of more serious problems.”

Remote Structural Health-Monitoring System Demonstration

In addition to the bridge at Rock Island, CERL will demonstrate a remote-monitoring approach for the I-20 Bridge that spans the Mississippi River at Vicksburg, Mississippi. OSD’s Corrosion Prevention and Control Program is sponsoring the projects. Following a pilot-scale test of a proposed structural health-monitoring system at ERDC’s Geotechnical and Structures Laboratory, the two bridges will be instrumented. CERL will monitor and collect data for one year, after which the equipment will remain on the bridges indefinitely.

“Each bridge will have a remote-monitoring system tailored to its specific needs,” said Sweeney. “The type of sensors used will depend on what information is critical to evaluate structural health and how it will be interpreted with respect to deterioration or damage.”

The demonstration technologies include Fiber Bragg Gratings, acoustic emission sensors, two sensors for corrosion (linear polarization resistor and electrical resistance type), accelerometers, strain gages, tilt sensors, and deflection/displacement gages, environmental data from a weather station, and videotape. The devices will transmit data to a software program that will filter out the “noise,” analyze performance based on engineering models, and provide meaningful output to the user. Certain values for the measurements will be programmed into the system to issue an alert via wireless communication if these values are exceeded.

DoD’s mission-critical steel-truss bridge is located at Rock Island Arsenal in Illinois. Photo courtesy of ERDC-CERL.

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The bridge at Rock Island, also known as the “Government Bridge,” opened in 1896. The top deck supports two rail lines while the lower deck accommodates about 10,300 vehicles each day. It has a swing span that can be opened to allow shipping vessels to pass through Lock 15. The structural health-monitoring system’s intent is to monitor corrosion and detect structural irregularities or changes to the bridge’s swing span.

The I-20 Bridge is a steel-truss-through-deck type and handles about 23,000 vehicles per day. Sensors will be placed on the east end, where two piers have been moving westward over time. The purpose of placing instruments on this section is to monitor the pier’s movement with the associated safety concerns and distress to structural members, as well as the span across the navigation channel between piers E-1 and W-1 of the structure.

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Ultimately, no inspection technique can provide a guarantee against catastrophic bridge failure. However, sudden bridge failures can be minimized through the use of these remote-monitoring techniques. In addition, remote structural health-monitoring techniques typically decrease the need for debate among those who maintain bridges. By using the new monitoring techniques, maintenance personnel could determine whether or not an individual flaw is actively growing and the probability that the flaw could lead to a major failure if left unrepaired.